Constraints on Beaming in Gamma-Ray Bursts

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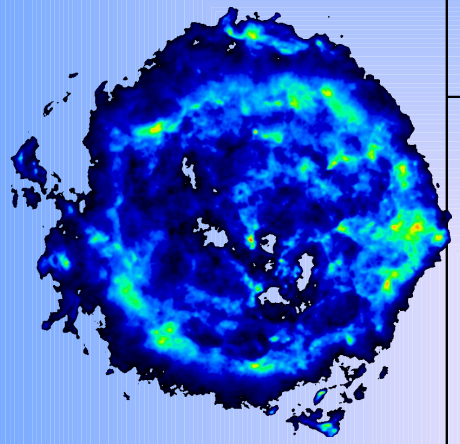
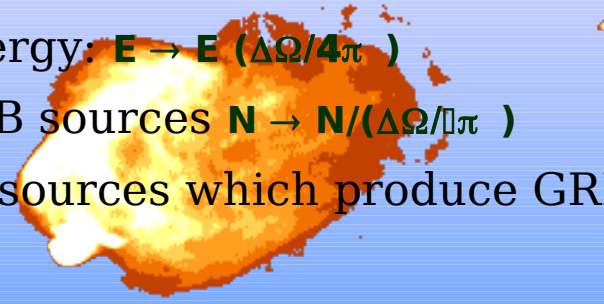


GRB	Redshift	Peak Power (10^{52} ergs s^{-1})	Energy (10^{52} ergs)
970228	~1.5-2.6	3-10	1.3
970508	0.835	0.13	0.6
971214	3.418	4	30
980329	~4	~10	~20
980425	0.0084	0.000011	0.00008
980703	0.966	0.13	11
990123	>1.6	4	>300!!

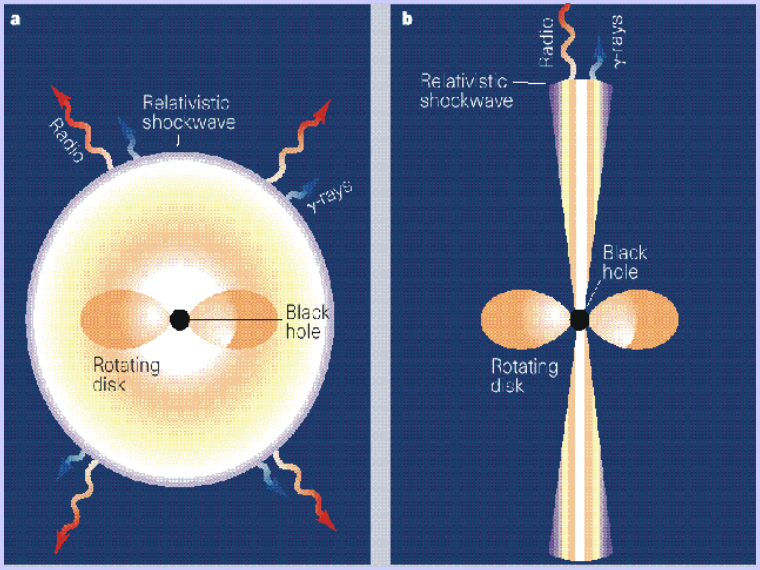
$1\ M_\odot c^2 = 2\times10^{54}$ ergs

- **Degree of beaming determines**
  - the total burst energy: **$E \rightarrow E\ (\Delta\Omega/4\pi)$**
  - the number of GRB sources **$N \rightarrow N/(\Delta\Omega/4\pi)$**
  - the nature of the sources which produce GRBs

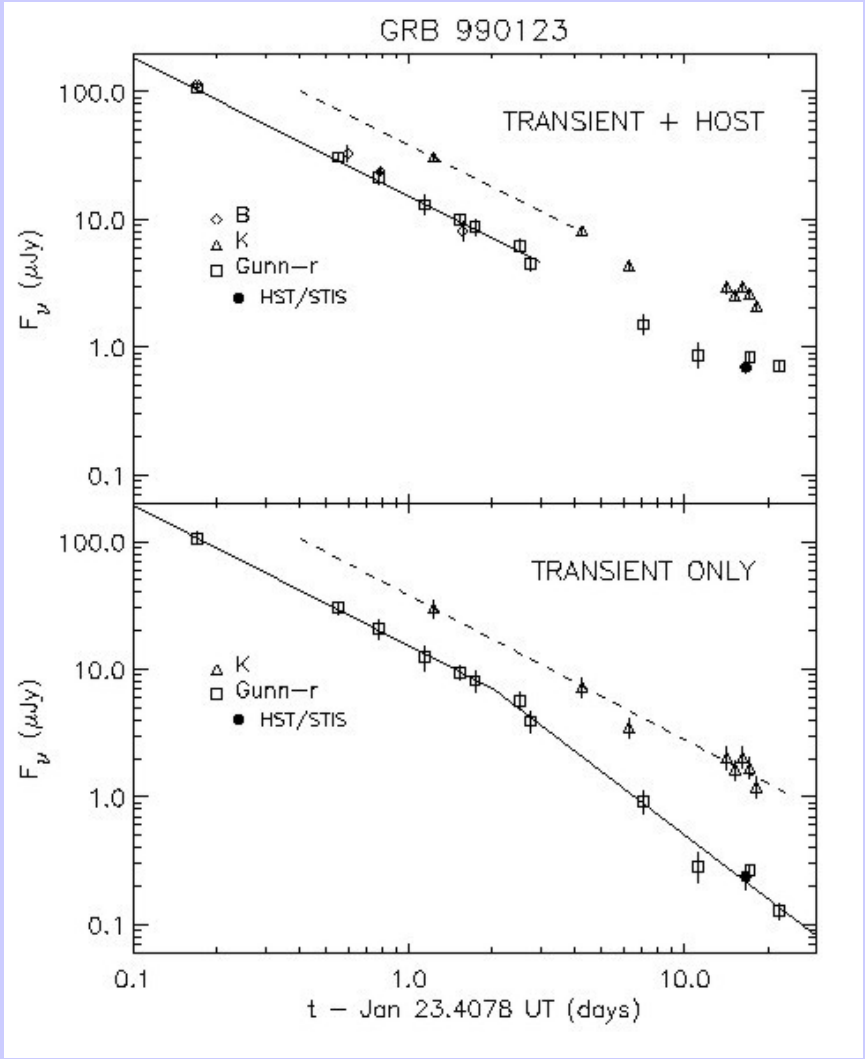


GRB 990123

- **Break in temporal index evidence for beaming?**



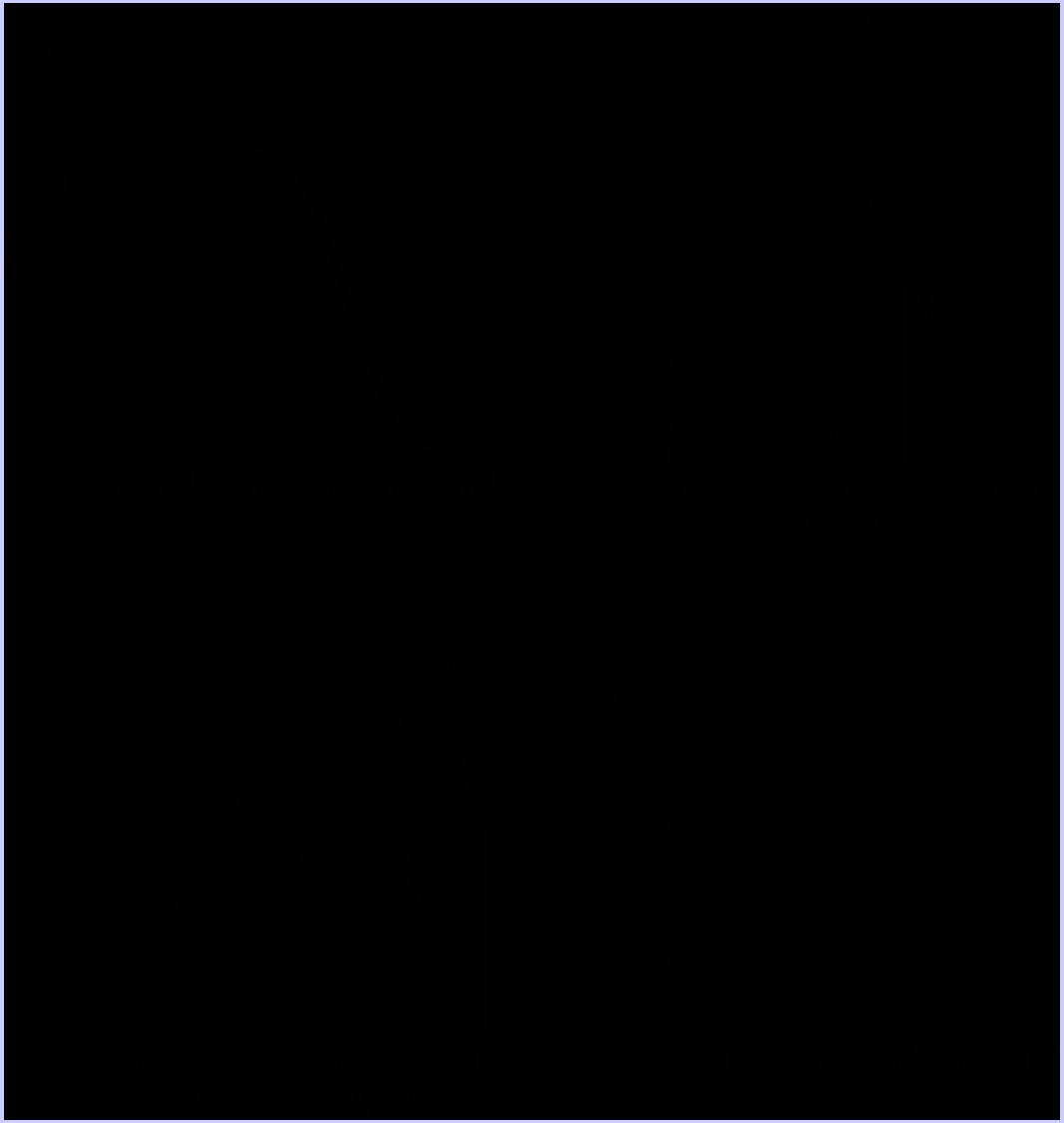
Baron, E. *Nature*, **395**, 635, 1998 (reproduced by permission)



Kulkarni, S. et al. *Nature*, submitted (1999) (astro-ph/9902272)

Blast Wave Model in the External Shock Paradigm

- **Explain all GRB phenomenology with single impulsive event; variability due to inhomogeneities in surrounding medium**
- **Observer sees emission from Doppler cone for portions of blast wave directed within 1/Γ of line-of-sight to observer**



$E = 10^{54}$ ergs; $\Gamma = 200$; $n = 100$ cm^{-3}

C. Dermer & J. Chiang (1999) in *High Energy Processes from Accreting Black Holes,* ed. J. Poutanen and R. Svensson, in press (astro-ph/9810222)

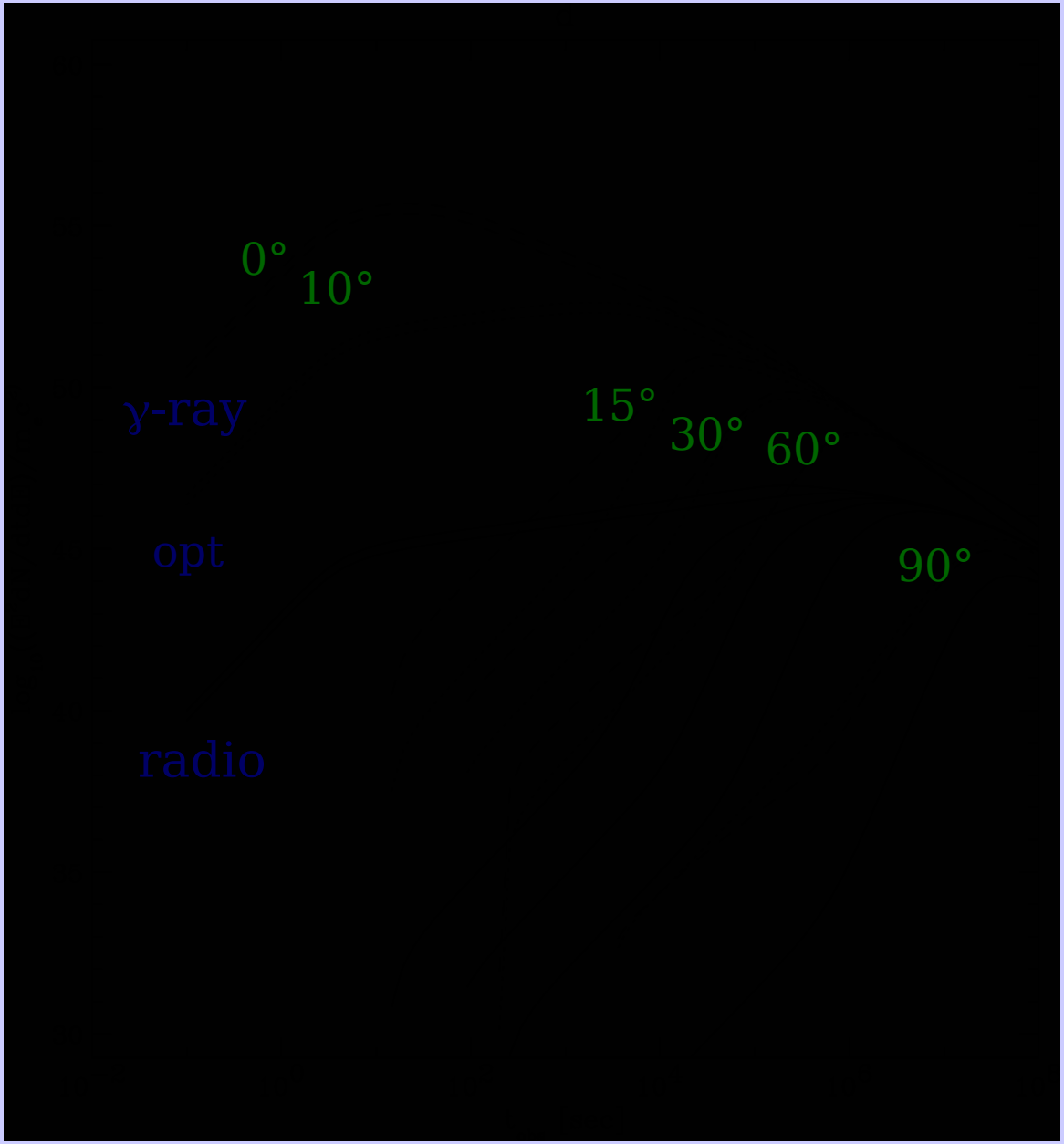
Beaming:
Opening angle of jet ψ = 10°

$\partial E/\partial\Omega = 10^{54}$ ergs/4π

$\Gamma = 300$

$n = 100\ cm^{-3}$

- **Break in temporal indices**
- **Statistics of misaligned sources (see Grindlay, J. *ApJ*, 510, 710, 1999)**



Beaming:

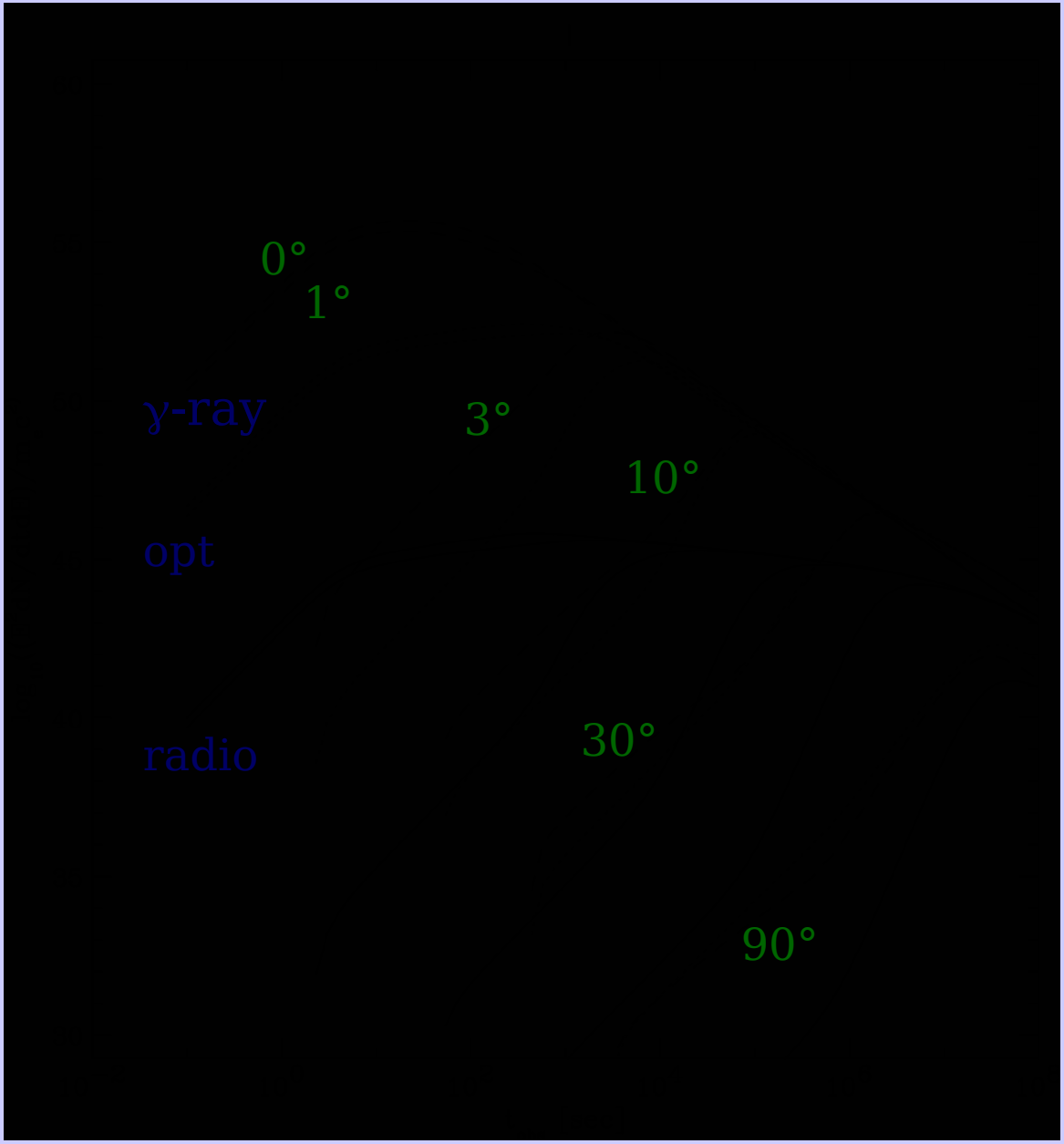
Opening angle of jet ψ = 1°

$\partial E/\partial\Omega = 10^{54}$ ergs/4π

$\Gamma = 300$

$n = 100\ cm^{-3}$

- **No break in temporal indices**
- **Power law decay of temporal profile**

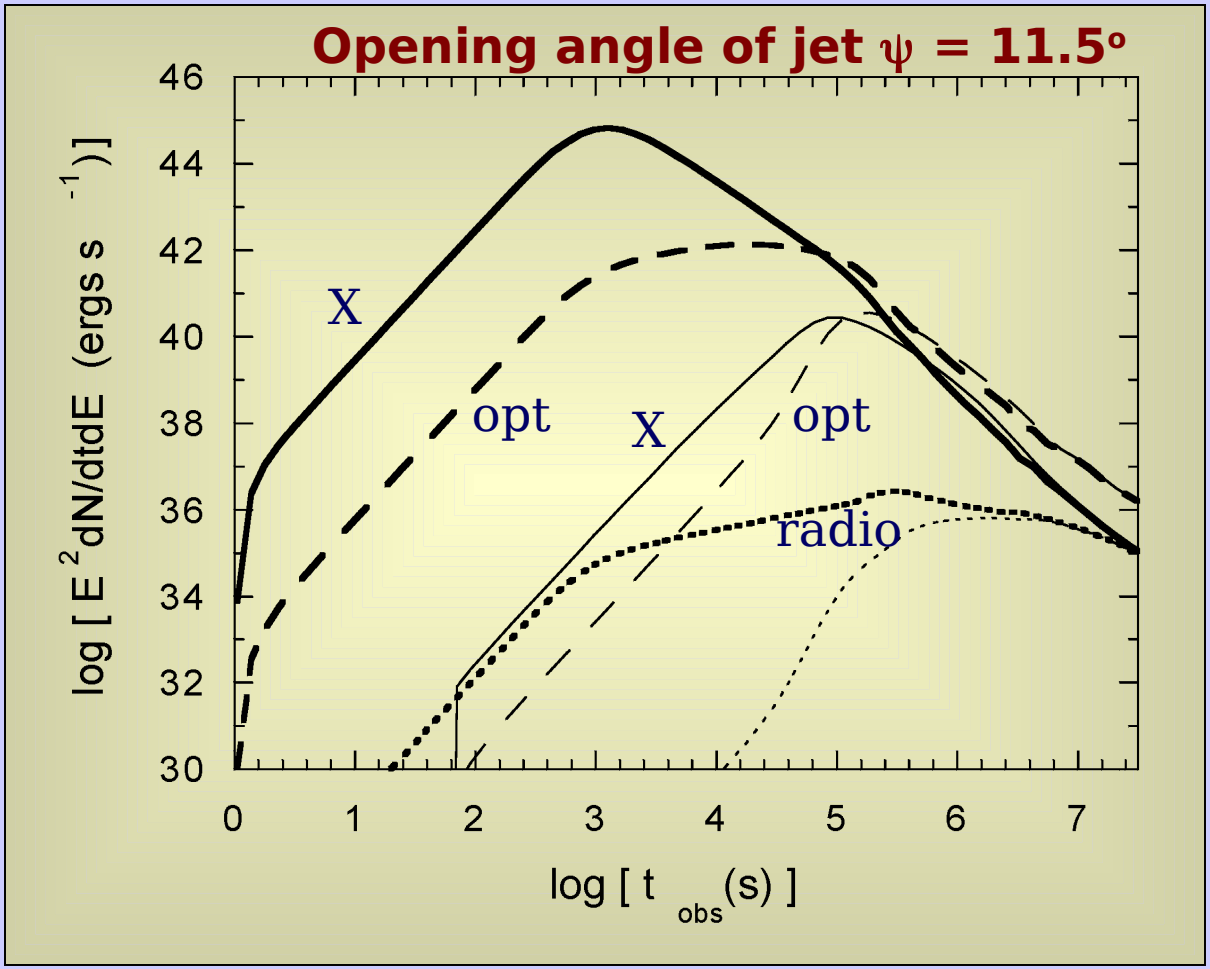


Beaming and Variability

Bold: along jet axis

Light: 20° off jet axis

- **Preferentially detect flaring synchrotron sources at highest photon energies in flux limited surveys**

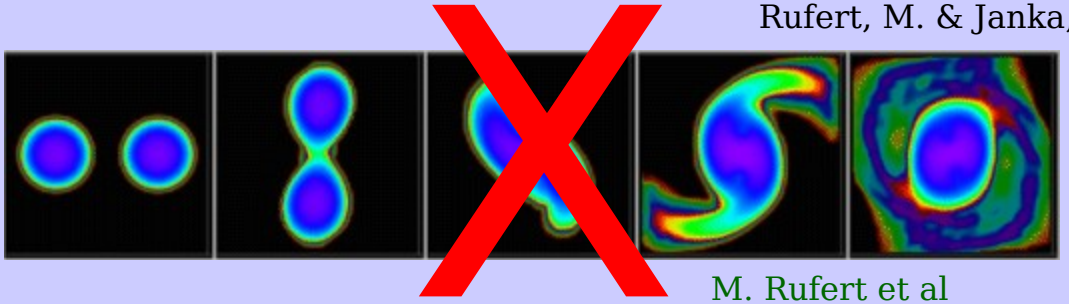


in *Veritas Workshop Proceedings*, ed. T. Weekes and M. Catanese, ***Astroparticle Physics***, in press (astro-ph/9901324)

Are GRBs beamed?

- **Break in temporal indices:**
  - **Beaming**
  - **Variation in density of circumburster medium**
  - **Cutoffs in electron distribution**
- **If beamed, minimum beaming angle > few degrees**
  - **→ coalescing neutron star models ruled out (maximum radiative energy ~ 10^{49} - 10^{50} ergs)**

Rufert, M. & Janka, H. *A&A*, **344**, 573 (1999)



M. Rufert et al

This talk posted at http://**gamma.nrl.navy.mil/dap-**